



Process optimization on ambitious sustainability goals through the framework of DGNB

Espenhein, Kasper; Jensen, Lotte Bjerregaard

Published in:

Proceedings of the 5th International Workshop on Design in Civil and Environmental Engineering

Publication date:

2017

Document Version

Peer reviewed version

[Link back to DTU Orbit](#)

Citation (APA):

Espenhein, K., & Jensen, L. B. (2017). Process optimization on ambitious sustainability goals through the framework of DGNB. In *Proceedings of the 5th International Workshop on Design in Civil and Environmental Engineering*

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal

If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Process optimization on ambitious sustainability goals through the framework of DGNB

Kasper Espenhein^{*1} and Lotte Bjerregaard Jensen¹

S112913@student.dtu.dk, lbj@byg.dtu.dk

¹ Civil Engineering, Technical University of Denmark, Denmark

The need for designing buildings with a sustainable approach is higher than ever before, but using building sustainability assessment tools, such as DGNB, is a comprehensive and complex activity. This has led to attempts to optimize the tangibility for usage of sustainability assessment tools in the design process. A holistic qualitative approach is used in this paper with the aim of mapping the structure of DGNB Office Building finding and prioritizing topics to address during a design process. Four experts from the Danish building sector were interviewed and their responses analyzed through the use of Grounded Theory. The findings expose that the project brief must define a healthy framework for both collaboration and projectmanagement, and a specific two-step approach to obtain the certification goal should be performed. The size of the criteria determined how it should be addressed in the project. DGNB was also found to have an impact on the architectural quality leading to certain architectural traits. An important finding was that it is paramount that all stakeholders take an integrated holistic approach when applying DGNB.

Keywords: Sustainability, DGNB, Process Optimization, Grounded Theory, Integrated Design Process.

Introduction

Global warming is not the only challenge the world is facing. It is one of the most urgent aspects to take actions upon, but other issues need attention if not to become equally critical. This becomes clear when evaluating areas such as material usage, bio-diversity, acidification etc. The limit for biodiversity loss for example exceeded in 2010 by a tenfold if one addresses the theory of “Planetary Boundaries” by Rockström *et al.* (2009), Figure 1. This has led the UN Convention for Biological Diversity to call for actions against “business as usual” production, behavior and consumption in order to avoid substantial loss of biodiversity (Secretariat of the Convention on Biological Diversity, 2014). However, this is just one many challenges that exist today.

These issues have, to some extent, their roots in buildings and the built environment. A common fact is that the energy consumption of the world building mass accounts for over 40% of the total energy consumption.

The building sector is at the same time a big part of the world economy. It is alone related to 10-40% of countries’ GDP and accounts for about 10% of all jobs in the world (UNEP SBCEI, 2013). Furthermore this has to be seen in relation to a normal person spending the majority of time indoor and that 70% of the world population will live in urban areas by 2050 (UN-Habitat, 2009). The dilemma of avoiding pushing the world into irreversible changes places an increasing number of

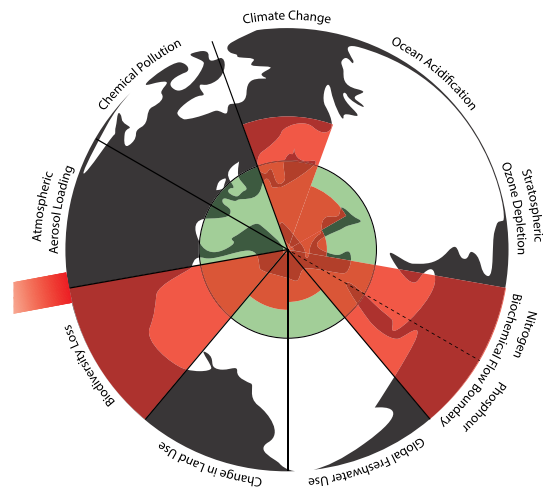


Figure 1. The planetary boundaries. By Rockström *et al.* (2009)

restrictions and performance requirements on modern buildings, which they must cope with. This feeds the need for assessing buildings with a sustainable assessment tool/system more than ever before. Previous to this development the ‘energy design’ was in focus, and the complexity of obtaining a building with a low energy usage was difficult, but it was catalyzed by the creation of the Integrated Energy Design (IED) assessment (Brunsgaard, 2016; Löhnert *et al.*, 2003), with different versions of this approach, such as Integrated Project Delivery (AIA, 2007), appearing the years after.

New approaches are now emerging, due to awareness of the bigger picture and the need of a broader approach than solely energy assessments. These approaches are called Building Sustainability Assessment Tool (BSAT). A BSAT addresses a building holistically through all dimensions of sustainability and offers a long list of criteria that has to be evaluated within the whole buildings life cycle. This has to be taken into an account when designing the building.

Sustainability assessments and certification is a complex affair because of the vast numbers of trade-offs that constantly have to be made during the design process (Schweber, 2013; Kreiner *et al.*, 2015). This challenge becomes even more pressing in the early design phase, where Ding (2008) argue that BSATs can have the highest possible influence due to the project being created and virtually no parameters are fixed. It is difficult in this stage for team members, such as architects, structural or MEP engineers to know which parameters that have a low or high impact on the total measured sustainability, and also when these parameters should be addressed.

The BSAT assessor that acts as a process manager tries to cultivate this process. This places a significant pressure and dependency on the assessor who, due to this, has a considerable impact on the final outcome (Brunsgaard, 2016).

Previous studies in BSAT

Much research has already been done within this area since the first versions of BSATs, and it can generally be categorized into two large groups. The first takes the aim of obtaining a better understanding of the BSATs through a mapping of the structural setup and the criteria's interrelations. The second research perspective takes the aim of understanding BSAT's impact on the design process. This leads to cases based on investigations of BSAT's impact on the design process and other management matters.

The two research set ups can be argued to have an impact on each other while also informing the general understanding of a BSAT, especially when the BSATs recently started incorporating the design process as part of the sustainability score (DGNB, 2016). Yet no research has been found where both research setups are applied in one study with the desire of creating more tangible and practical guidelines for design teams. This lack of research has been argued to hold possible findings that would benefit the overall understanding (Schweber, 2013; Schweber and Leiringer, 2012). The following is an attempt to fill this gap.

Figure 2 is a study from Khezri (2011) and it shows the different BSAT's internal division in

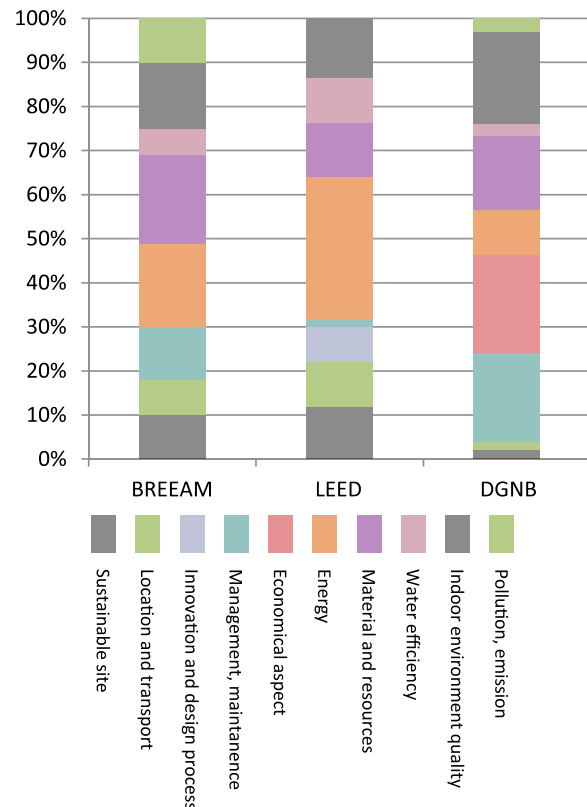


Figure 2. The separation in generic categories of different sustainability systems by Khezri (2011).

sustainability categories and also how significant the difference between the BSATs is. Wallhagen et al. (2013), Khezri (2011) concludes that DGNB is the only BSAT that covers economical aspects, whereas other only partly cover this. Architecture is barely mentioned in all the specified literature. Only a few articles address the architectural aspects. Yuce (2012) evaluates the importance of the generic categories from DGNB, LEED and BREEAM. They are evaluated according to a criteria ranking where the different criteria were ranked according to their importance set by the European Commission called SuPerBuildings (SuPerBuildings, 2012). The findings define and categorize architecture and cultural considerations as less important compared to comfort, energy and materials, which are categorized as very important. This assertion of architecture and culture being less important is also addressed by Naboni (2013) who argues that architectural values lack presence in all three mentioned certification systems, i.e. BREEAM, DGNB and LEED.

BSATs and design process

Brunsgaard (2016) performed case studies on different hospital projects in Denmark to decode which effect the DGNB system has on the design team and the process. It was found that DGNB stress the importance of collaborating from the very beginning with the whole team and the DGNB assessor, to get DGNB implemented early in the

design process. The authors also found that the contract has a great impact on the design process, but they also stated that a team's commitment for achieving in the DGNB setup depended on feeling of ownership for the project. This is equal to some findings of Schweber and Haroglu (2014) that did a similar study on BREEAM. Bruunsgaard (2016) concludes that a BSAT-assessment "just added another layer to the project" along with layers from other stakeholders.

The similar study by Schweber and Haroglu (2014) explored and mapped the effect of assessment with BREEAM on the design and construction process. The findings were that individual commitment from experts also had a great impact on the team's collaboration and thus the final result. They also found that a better design process were present when all team members knew and understood the principles of the BSAT focused design process. Lastly their study also showed that an internal BREEAM assessor could contribute noticeably to the design process, and that an assessor could compensate for lacks in the design team.

Schweber (2013) studied the same cases with another focus. Here the author's focus was on the effects of BREEAM on the client, the team and the design process. The study investigated the effect in different cases where the team's knowledge about BREEAM varied. It was found that BREEAM had a considerable impact on the standard practices because of the bureaucratic method with documentation handling. It was concluded that BREEAM had a risk of undermining the client's confidence of the tool due to failure of adapting to a known design process.

Decision making in BSATs

Many have studied the possibility of optimizing the usability of BSATs by studying Design process optimization and Multi-Criteria Decision Making (MCDM).

There have been many attempts on making a BSAT more tangible, understandable and usable by using computational optimization. Evins (2013) identified 74 studies that in different ways applied different types of optimization methods on different fields of a building, however, only about half of them took a multi-criteria (MCDM) approach. Especially areas such as envelope design, building management systems (BMS), HVAC-systems and renewables were in focus. The author concludes that the use of MCDM receives an increasing interest from the building sector.

Kreiner, Passer and Wallbaum (2015) analysed the Austrian adaptation of DGNB called ÖGNI for the possibility to create a systematic approach to the sustainability that could be utilized in the early design phase. This study was performed through the mapping of the criteria interdependency by using the

MCDM. Their findings clearly showed the internal structure of ÖGNI and each criteria's importance, making it much more capable to determine which criteria to work with early. The authors conclude that the work presented has the possibility of being implemented in BIM to improve the sustainable performance. Medineckiene et al. (2015) did a similar study with the Swedish version of sustainability certification system called Miljöbyggnad using a different MCDM method. They conclude that the final output of using the MCDM guides the authors closer to an understanding of the Swedish system's setup, impacts and usability when it was used in a design process.

Delimitations

BSATs are used globally however this research has the delimitations seen in Table 1. The amount of BSATs in the world increases rapidly and they all differ due to climatic, cultural and legal differences in the countries. DGNB is chosen as the only BSAT evaluated in this study due to its scope and level of detail and that it is was chosen by the Danish Green Building Council to be implemented generally in the Danish Building industry.

The empirical data available differs for each scheme, and this leads to the last delimitation; '(DGNB) Office Buildings' as the only scheme due to it being the oldest and most used in Denmark.

DGNB evaluates a building on five different main categories, and these are defined the following way: **Environmental quality**, evaluates the environmental impact based on seven indicators: Global warming potential, Ozone depletion potential, photochemical ozone creation potential, Acidification potential, Eutrophication potential over an evaluation period of 50 years. **Economic quality**, incorporates the aspects such as Life Cycle Costs (LCC) with the aim of reducing the total costs for the building during the period of 50 years. **Social quality**, focuses predominantly on health and user satisfaction. It separates out the different aspects of comfort and also scopes the buildings functionality. **Technical quality**, focuses also on the technical quality of the classic building aspects such as the technical quality of the solutions, such as sound insulation, building envelope, future adaptability and disassembly. **Process quality**, scopes the quality of the planning and the design process of the building along with the construction process. It seeks to create guidelines and recommendations for the management of the process integrating DGNB in the design process. **Site quality**,

Table 1. Research delimitations

Delimitations	Description
BSAT	DGNB
Location	Denmark
Certification scheme	Office buildings

Table 2. DGNB evaluation matrix by DGNB (2016)

Theme category	Criteria group	Criterion	Criterion name	Sub weighting	Criteria weighting	Group weighting
Environment	Life cycle assessment	ENV 1.1	Life Cycle Impact Assessment	7	7.9%	22.5%
		ENV 1.2	Local Environmental Impact	3	3.4%	
		ENV 1.3	Responsible Procurement	1	1.1%	
		ENV 2.1	Life Cycle Impact Assessment – Primary Energy	5	5.6%	
		ENV 2.2	Drinking Water Demand and Waste Water Volume	2	2.3%	
Economy	Life cycle cost	ENV 2.3	Land Use	2	2.3%	22.5%
		ECO 1.1	Life Cycle Cost	3	9.6%	
		ECO 2.1	Flexibility and Adaptability	3	9.6%	
		ECO 2.2	Commercial Viability	1	3.2%	
Social	Health, comfort and user satisfaction	SOC 1.1	Thermal Comfort	5	4.0%	22.5%
		SOC 1.2	Indoor Air Quality	3	2.4%	
		SOC 1.3	Acoustic Comfort	3	2.4%	
		SOC 1.4	Visual Comfort	3	2.4%	
		SOC 1.5	User Control	2	1.6%	
		SOC 1.6	Quality of Outdoor Spaces	2	1.6%	
		SOC 1.7	Safety and Security	1	0.8%	
	Functionality	SOC 2.1	Design for All	2	1.6%	
		SOC 2.2	Public Access	1	0.8%	
		SOC 2.3	Cyclist Facilities	1	0.8%	
	Quality of the design	SOC 3.1	Design and Urban Quality	3	2.4%	
		SOC 3.2	Integrated Public Art	1	0.8%	
	Plan layout	SOC 3.3	Plan Layout	1	0.8%	
Technical	Quality of technical configuration	TEC 1.1	Fire Safety	2	4.1%	22.5%
		TEC 1.2	Sound Insulation	2	4.1%	
		TEC 1.3	Building Envelope Quality	2	4.1%	
		TEC 1.4	Adaptability of Technical Systems	1	2.0%	
		TEC 1.5	Cleaning and Maintenance	2	4.1%	
		TEC 1.6	Deconstruction and Disassembly	2	4.1%	
Process	Quality of planning	PRO 1.1	Comprehensive Project Brief	3	0.6%	10.0%
		PRO 1.2	Integrated Design	3	0.6%	
		PRO 1.3	Design Concept	3	0.6%	
		PRO 1.4	Sustainability Aspects in Tender Phase	2	0.4%	
		PRO 1.5	Documentation for Facility Management	2	0.4%	
		PRO 2.1	Environmental Impact of Construction	2	0.4%	
	Quality of construction activities	PRO 2.2	Construction Quality Assurance	3	0.6%	
		PRO 2.4	Systematic Commissioning	3	0.6%	
Site	Site	SITE 1.1	Local Environment	2	0.0%	0.0%
		SITE 1.2	Public Image and Social Conditions	2	0.0%	
		SITE 1.3	Transport Access	3	0.0%	
		SITE 1.4	Transport Amenities	2	0.0%	

is evaluated separately from the building and has no effect on the final points given. Here the buildings location and relation to its surroundings is considered where aspects like transport access and local urban life is included. Together, all these six categories make up the foundation for the evaluation as illustrated in Table 2.

The certification process with DGNB is voluntary and DGNB's elements can be used even if certification is not desired. There is also the possibility to do a pre-certification during the design process, where the intention is to determine sustainability objectives, which can bring clarity to the project and its ambitions. After construction the final certification can take place, and this process must be done by a DGNB auditor who is responsible for gathering and handling all the relevant documentation. A building must as a last step

undergo a conformity check, which is where a third party of experts check and evaluate the documentation for the building. The certificate level varies according to the buildings total performance. Weighting and summing the scores of the 40 individual criteria determine the total performance. There exists a lower limit that each of the five main categories must comply with, if a certain score is desired. This is to ensure that a truly holistic approach takes place. The specific certification levels and the corresponding total and minimum performance indexes can be found in Table 3.

Table 3. DGNB nomenclature for awards

Total Performance Index	Minimum Performance Index	Award
>80%	≥65%	Platinum
>65%	≥50%	Gold
>50%	≥35%	Silver
>35%	-	Bronze

DGNB states that close to 80% of the required documentation have to be done anyway compared to a conventional design project. However, the formal requirements from DGNB has not been considered in this statement (Ebert, Eißig & Hauser, 2011), and this statement is also only for the German version.

Method

The aim of the research is to investigate and map the structure of BSATs in order to find, understand and synthesize key aspects that together can catalyze the usage of BSATs in a design process. The objective being to obtain thorough insight of how BSATs work by focusing on three aspects: how the BSAT is structured, how a team uses them and how they are applied and affecting a building. This leads to the following research questions:

Which criteria are important to address and which criteria are difficult to work with due to their complexity and interrelations to other criteria?

How are BSATs implemented in the design process and which criteria should be addressed earlier than others during the design phases?

Does BSATs have an impact on the architecture of a building when there is an aim of achieving a high score in BSATs?

In order to work with these questions they were grouped according to three aspects of the research objective; Theory (the DGNB framework), Workflow (the design process) and architecture.

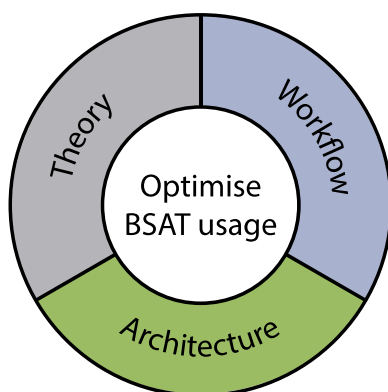


Figure 3. The three research aspects.

Grounded Theory

Defining which type of approach and research paradigm to use in the research can be a challenge

when working with topics that has the potential to give good results from both an interpretive and the positivist approach. The positivist paradigm devotes to the creation of theoretical propositions by the use of formal logic rules and hypothetico-deductive rules, which is tested against the four requirements of theoretical propositions (Lee, 1991). This is in contrast to the interpretive paradigm, which states that people develop their own meaning to the world around them and also to their own acting behavior within it. Relating this to the area investigated one could easily argue for the positivist approach because DGNB has been built on elements from this paradigm. However, contradictions emerge when the research questions regarding workflow and architecture is taken into consideration. The world of architecture, and all its aspects rests highly within the interpretive field and it cannot be confined in equations. Furthermore the workflow aspect is also a field where the interpretive approach is predominantly used because a construction project can be argued to be within the definition of a 'wicked problem'. Schweber and Leiringer (2012) argue that areas that are addressed through an opposing research paradigm will reveal other conclusions that can lead to a broader perspective.

Summarizing this leads to a conclusion where the majority of the research questions favors the interpretive approach. Hence the use of Grounded Theory from social science as an approach to the analysis of the results is found best for this research.

Grounded Theory

Grounded Theory (GT) is an inductive, systematic and dynamic way of creating an understanding of the collected data, step by step, with the aim of generating a theory that explains the events, tendencies and structures within the data and the area of research (Charmaz, 2006). GT is not a theory in it self, but rather a method to develop a theory which is based on the collected data. The process of GT is to gradually condense the research data by indexing it with short codes so it can be grouped into larger categories that show tendencies and patterns that create the foundation of the evolving theory.

This research uses the methodology defined by Charmaz (2006), and is chosen because of its practical view on the theory along with a step by step definition of the theoretical frame that a researcher can follow. The different steps of GT are: Data collection, Coding, Memoing, Sampling and Generation..

The steps of GT

Initial Coding - The aim of Initial Coding is to capture the core information in the data such as actions, statements, points of view etc. in an objective way, so it reflects the data in a condensed version. The result should be research data in a more tangible text form. **Focused Coding** - Focused coding distillates and conceptualizes the initial codes down to fewer codes that represents a bigger part of the research data. Thus a big part of the work is to find connections between the initial codes that can lead to a broader and generic definition of the early findings. **Theoretical Coding** - The theoretical codes starts to conceptualize the relations that the initial and focused codes might have. The aim of the theoretical coding is to construct a frame or pattern of how all the initial and focused codes relates to each other in research data. **Memoing** - is an ongoing process where the researcher scribbles down and save any thoughts about ideas, concepts, and comparisons of data that could contribute to the creation of the overall theory. The format of the memos is informal and should only relate to the researcher. **Theoretical sampling** - Charmaz (2006) is where the researcher re-evaluates the codes and memos created with aim to look for new information. This is a highly iterative process where one goes through the entire research data to look for any aspect that might be missing. This process continues until a point of *saturation*, where the researcher no longer can find new elements. **Theory Generation** - This step is the actual construction and writing of the theory. The different categories combine the memos, the framework of the theory and its scope. Finally the constructed theory must be evaluated in light of the research objective, scope, level of detail in order to obtain a sound theory/finding.

Participants

Four experts from the Danish building sector participated in the interviews and they were chosen based on three different requirements. (1) The first was they had to have a thorough understanding of the structure of DGNB, meaning they either had to be DGNB auditors or have don a Ph.D. thesis with DGNB as a core element. (2) The second requirements secured a variation in the participant's professional area. This requirement was established to secure a variation in the responses due to different experience with DGNB and its impact. (3) Lastly the participants had to have enough experience with the design process thus securing reliable answers based on experience with a least one project where DGNB were implemented. The participants have the following professional profiles:

Participant 'IG'. The participant is a MEP-engineer and project director at a large engineering consultancy. IG is a DGNB auditor in office buildings with many years of experience in

sustainable building assessment. **Participant 'JSK'**. is an architect and only DGNB consultant but holds a Ph.D. in sustainability where JSK has obtained thorough knowledge about the DGNB setup and the calculations. **Participant 'JK'** is an architect and sustainability manager in an architectural office. The participant is a DGNB auditor (office buildings) with about 4 years of experience in DGNB and teaches in parts of the DGNB education in DK GBC. **Participant 'CD'**, is an MEP-engineer and sustainability leader in a consultancy firm. Participant four is a DGNB auditor with about three years of experience in DGNB, BREEAM and LEED.

Interviews and transcribing

The interviews were executed as semi-structured interviews.

Theorizing

The key statements from each interview that referred to the same thing were grouped/categorized together and thus supporting a specific area. The emerging areas were seen in relation to the research objective themes; Theory, Workflow or Architecture. This created a clear separation of the findings and minimized overlap but was time consuming because of its non-linearity and iterative nature and due to the importance of doing the theoretical sampling, until the point of saturation.

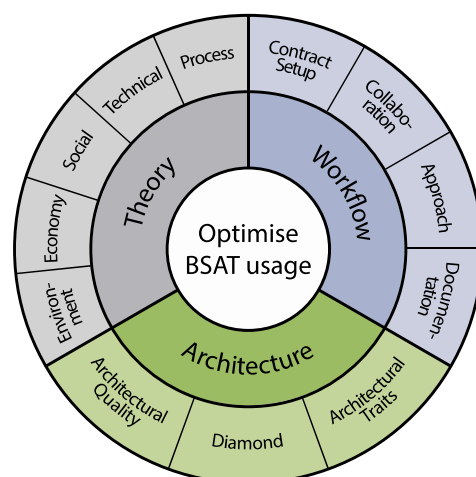


Figure 4. Research aspects and found categories

Results

Using the grounded theory on the four interviews led to a number of different categories emerging for each research question/aspect. The findings within the three predetermined aspects led to a total of 12 categories structured as seen in Figure 4. The

Table 4. Environmental Category

Life Cycle Assessment	IG	JSK	JK	CD
The indoor climate is a significant part of the building's quality and should be considered in the design process.	X	X	X	
The building's energy consumption is a significant factor due to the complexity of the building's structure.	X	X		
The building's safety and accessibility are important factors.	X	X	X	CD
The building's environmental impact is a significant factor due to the complexity of the building's structure.	X	X	X	
Within the project, there is a simple process but requires a significant amount of work in documentation.	X	X	X	X
The time spend versus the points gained makes people avoid the criterion to the latest or even skip it.	X	X	X	X

categories emerged based on the requirement that at least two statements supported each other. The categories were sized according to the certainty of the conclusions on the data. Hence some categories can be evaluated to be adequately corroborated by statements to hold a conclusion, whereas others only hold enough data to show a tendency.

The Theory aspect

The first aspect of the research objective attempts to identify which of the 40 criteria are important to address in terms of attention, interrelations or impact on other parts of a building project. This aspect used the framework of DGNB to categorize different interview responses and statements. The interviews exposed that 26 of the criteria were addressed. This equals 65% of all 40 criteria and 72% when excluding the site related criteria that only has been mentioned briefly by two participants. The SITE category was only mentioned briefly in two of the four interviews, which means it has been neglected from this research.

Tables 4 and 5 summarises the findings through statement where the “x” marks the contribution from the participants to each statement.

Environment category

The environmental category, as seen in Table 4, was found to have importance for all participants with a special focus on two criteria ENV 1.1 - LCA and ENV 1.2 - Local Environmental Impact.

Three participants responded to the Life Cycle Assessment (LCA) and stated that it was an important criterion to address due to its size and also due to its complexity and impact on many other parameters of a building such as the materials/products used. The time spend on the LCA were also pointed out as being a factor that contributed to its importance. The participants advocated for addressing the LCA in bits throughout the design process while varying it in the level of detail. They e.g. suggested a qualitative assessment in the very first phases in order to optimize the work with the LCA and also to let it

Table 5. Economical Category

Life Cycle Cost	IG	JSK	JK	CD
The LCC criterion is of high importance due to the criteria size, its interrelations and interest from the client and stakeholders.	X		X	X
The LCC is not difficult but takes time partly because of its indirect relations to all aspects of the a building.	X			X
It is an advantage for architecture, advocates for passive solutions, lowers running cost and generally leads to a cheaper building over the life time.	X	X	X	X

become an active design tool rather than a passive evaluation tool.

The Local Environmental Impact, which is criterion ENV 1.2, were defined as being the most time consuming criterion compared to its size by all four participants, which elaborated that the process was simple but the documentation was the issue. It was an “all or nothing” criterion meaning that it was impossible to achieve a score if just one document was missing in the documentation.

Economical category

The participants primarily responded or mentioned the Life Cycle Economy (LCC) within DGNB's economical category. The key findings from this category can be found in Table 5. The LCC was found to be one of the most important criterion within the DGNB assessment system. Three out of four participants contributed to the first statement within Table 5, making it highly important.

The LCC was not found difficult to work with, however it was found time consuming due to the many stakeholders within the project along with all the interrelations to e.g. energy usage, glazed areas, architectural details etc. All participants contributed to the statement about LCC being a valuable tool for many facets like architecture, passive energy design etc. because it expanded the economic horizon. A participant noted that the LCC became an advantage to architecture because it supported choice of robust good and long lasting building materials.

Social Category

Two participants defined a company's CSR-policy to be an element determining which criteria to receive the most attention. The key findings can be seen in Table 6. A general finding was that most of the indoor climate aspects are in focus. One participant explained this with the indoor climate being connected to the employee's productivity and thus the company's economical result. However, other participants also mentioned that ambitious indoor climate requirements had a negative impact on the LCC due to larger installations.

All four participants noted that the social category had a lot of criteria that varied in size,

importance and awareness in different design teams. ‘Safety and Security’, ‘Design for All’ and ‘Cyclist Facilities’ were mentioned when asked for criteria that were easy to implement and had a positive effect on the total level of sustainability. These criteria could be implemented without much work and were often received positively by the client.

Technical Category

The technical category was in general not mentioned during the interviews, and when the participants was about it, they stated that most of what was within this category already was implemented during a normal design process. This was either due to the project brief or the building regulation. Thus no specific statements were found relating to this category.

Process Category

This process category has similarities with the Workflow research aspect however it has a different angle and addresses the more DGNB specific actions that are suggested.

All four participants found the process category in DGNB very useful through all phases of a design process because it created assurance for quality. They generally found it quite comprehensive and time consuming, but when asked if it was worth the effort they all agreed that it was. The participants also focused on the contract and tender phase element of the process. They all argued that a contract or project brief had to include specific requirements to parts of DGNB to create common understanding and an equal level of ambition. Additionally two of the participants mentioned that it was important to set an aim of how to obtain the rest of the DGNB points when having defined the clients core criteria.

In general, many of these elements could be traced back to the creation of the project brief, and three participants stated that the work of the client advisor during the creation of the project brief had a significant influence on the end result in the Bsaf. Three participants also found it important to create design concepts for areas, such as accessibility, that were normally not seen as important in early phases. The participants linked this approach with criterion PRO 1.3 and underlined its importance. Two out of the four participants addressed the fact that having a simple and sound proposal for each of the required concept categories made the process much more tangible for the client and the design team and enhanced collaboration.

Workflow research aspect

This second aspect of the research objective attempts to identify how a design team should work when designing a building with a high DGNB score. This

Table 7. Process Category

Contract and Tender Phase	IG	JSK	JK	CD
The contract should contain a clear set of requirements to the process and the delivery, preferably directly from DGNB, in order to avoid misconceptions.	X	X	X	X
An aim and approach should be set on the how the rest of the criteria should be addressed.			X	X
The client councilor has a big responsibility of creating a healthy underlying basis for the contract in the earliest phases	X	X	X	
Design Concept Creation	IG	JSK	JK	CD
The creation of design concepts comes by itself in some areas like energy design. It is therefore important to focus on concept creation for overlooked parts	X	X	X	
Creating simple and sound concepts makes it tangible for the client.	X			X

workflow should include responses to ideal collaboration and approach to the DGNB criteria.

As mentioned earlier, this aspect would potentially hold some overlaps with the theory aspect and its ‘process’ category. The following text therefore tries to illustrate how these areas scopes differently. **Contract setup** - this area gathers the responses from participants concerning how a contract should be to embrace a good workflow.

Collaboration - this area focuses on specific responses to how a team should collaborate during the design of a building. **Approach** - addresses the responses that relate to what and how to approach issues concerning parts of the building in given situations. **Documentation** - this gathers the responses from the participants about the documentation required by DGNB.

Contract Setup

The general requirements for the workflow had to include specific requirements, optimally specific criteria from DGNB, for the securing a sound contract. If performed well it motivated the team for completing a DGNB certification. This was a point all participants found to agree (Table 8).

Collaboration

Table 8. Contract Setup

Requirements	IG	JSK	JK	CD
Just as general contract requirements should there also be set specific requirements to workflow / collaboration	X	X	X	X

Table 9 shows the responses for ‘collaboration’. The optimal design process when designing with DGNB were found to be similar to any other project following the principles of an Integrated Design Process. Despite this did the participants find it important for the team to understand the exact scope of work related to DGNB and also the required steps to get there. However this experience for the participants was not unique for DGNB projects.

Table 9. Collaboration

Contract and Tender Phase	IG	JSK	JK	CD
The design process incorporated in DGNB is similar to IED, but everyone must understand the method to have a smooth process.		X	X	X
DGNB Assessor	IG	JSK	JK	CD
There needs to be a definitive distinguish between the project manager's and the DGNB assessor's areas of responsibilities. Yet they still had to work and communicate closely.	X			X

A more specific element for DGNB was the scope of work performed by the DGNB assessor. Two of the participants noted the importance of understanding the difference between a project manager and the DGNB assessor, and how their scope of work differed, since one person could not handle the work of both. However, they still had to work closely together, and the assessor should focus on the communication of DGNB matters, along with creating clear communication of the required documentation. Lastly one participant mentioned that a DGNB assessor's previous experience had a big impact on the project outcome.

Approach

Table 10 shows the responses concerning 'collaboration'. When asked for how the participant did an early stage assessment, three participants responded that they made a qualitative assessment. One participant described this assessment as; using DGNB criteria as questions you had to answer in a short text. Two other participants found it important to address and implement the parts from DGNB's process category to the project at an early stage because it held a possibility to create a good foundation for collaboration when the criteria were defined and supervised from the start.

For the general assessment there was a common concord that a team should maintain a holistic perspective and avoid sub-optimising certain criteria, because it could lead to a team spending too much money and time on achieving a certain score in e.g. indoor climate, resulting in little time and little fund left for some of the other issues. Lastly, bigger

Table 10. Approach

Early Stage Assessment	IG	JSK	JK	CD
The early stage should be addressed in a qualitative matter, scoping as much as possible. Focus areas from clients should be addressed more specifically.		X	X	
The process category must be addressed in detail within the early stage to create a good foundation for collaboration.	X			X
General Assessment	IG	JSK	JK	CD
It is important is to maintain the holistic perspective and avoid sub-optimizing a certain criterion.	X		X	X
The biggest criteria should be addressed stepwise and multiple times through the phases	X	X	X	

Table 11. Documentation

Amount	IG	JSK	JK	CD
DGNB places considerable requirements to the amount of documentation, though, it is reasonable since most of the documentation is made anyway.	X	X	X	
Consequence	IG	JSK	JK	CD
The consequence of a high level of documentation is generally resistance.	X	X	X	

Table 12. Architectural Quality

Materials and Solutions	IG	JSK	JK	CD
The LCC advocates for robust, good and long lasting materials due to maintenance, fixing etc.		X	X	
DGNB advocates for simpler solutions through the desire of design disassembly.				X
Quality Measure	IG	JSK	JK	CD
Having architectural competitions is an indirect approach from DGNB's site to cultivate architectural quality.	X	X	X	X
There is an insufficient amount of points that directly evaluates the architectural quality in DGNB.		X	X	X
Consequence	IG	JSK	JK	CD
The building can have the highest score possible in DGNB but will not be sustainable if the architecture is terrible.	X	X		X

criteria should be addressed step-wise throughout the design phases because of their complexity and interference with other changing criteria.

Documentation

The statements to the documentation can be seen in Table 11. The amount of documentation was mentioned as an influencing factor on the project. Three participants found that DGNB increased the amount of documentation compared to a traditional project, yet the requirements were found reasonable since much of the documentation were made anyway.

A part of the participants had previously met challenges in a team, which was a consequence of the increased level of documentation. Some team members were generally against the extra work and documentation required, because they failed to understand the purpose of the work. Some participants mentioned that this could be solved by everyone understanding the DGNB process requirements.

'Architecture' research aspect

The third and last aspect of the research objective attempts to identify which influence the DGNB certification system has on the architecture - if a certain pattern can be found in the quality or the typology etc.

Architectural Quality

The architectural quality became a dominant element of the interview with all four participants when asked which impacts DGNB had on the architecture. Again,

as mentioned before, the LCC was highlighted as an example since the tool supported the use of lasting and robust materials for the building envelope. Another facet of the architectural quality was the joinery or the assembly of the building. It was mentioned by one participant that the requirements for design for disassembly in DGNB led to some projects actually having technical solutions that were simpler and easier to take apart in the building's End of Life phase. In relation to this one participant mentioned that DGNB usually helped with underlining the importance of some aspects of a building due requirements, but that architecture fell out of the scope of DGNB.

There was a general concord between the participants addressing this area that architectural competitions were a way to push forward for architectural quality because a jury evaluates the projects on an overall level (a competition gives scores in the DGNB system). But architecture in general lacked presence in DGNB in terms of explicit evaluation and points given for good architecture. This lack were seen as a considerable shortage of DGNB and its quality measure by several of the participants, however, DGNB were currently developing a solution to this, which is discussed in this paper in the following paragraph.

The consequence would be buildings that have a high certification level in DGNB, i.e. gold or platinum, but lacked architectural quality and thus in the end could be said not to be sustainable if architectural quality is what makes a building last for decades. The participants were aware of the previous cases with German buildings having a high score in DGNB lacking architectural value. The participants used words as 'too simple' and 'banal' to describe the buildings and said that the industry had learned from those cases since, by giving the architect the 'space' needed for creating good architecture.

Architectural Traits

When the participants were asked about architectural traits they were also asked if they saw the same tendency of traits present for engineering when working with DGNB. The responses were generally that this did not exist because the engineering consultancies generally had a more company specific profile that determined their approach, rather than a specific project. Three of the participants agreed to the statement of DGNB influencing the specific architectural solutions negatively. One participant noted that the original intention of DGNB were to create a frame with performance based requirements that give the design team a higher freedom to design a good solution, but this was generally not really seen by the participants. This made the participants advocate for a revision of the criteria.

Table 13. Architectural Traits

DGNB Impact	IG	JSK	JK	CD
DGNB does provoke architectural traits and it is not always for the better.	X	X	X	X
Specific Consequences	IG	JSK	JK	CD
DGNB's specific solutions were e.g. passive design approach, or windows in two sides of a building are a must.		X	X	X

The specific consequences mentioned by the participants to this issue were for example the requirement concerning number of orientations of the building. Two participants also outlined that the extensive use of the passive design methods also had a big impact on the buildings since it created a monolithic mass, or identical typology, but this had little to do with the DGNB setup itself. Lastly, when asked what impact this specific requirements had on themselves and their work they replied that they tweaked their mindset or their working routine to draw it as defined in DGNB to avoid future problems.

Diamond

Every participant answering 'yes' to the question about DGNB influencing the architectural traits and the architecture having too little influence on the criteria, also mentioned the new initiative from DGNB; Diamond.

Diamond seeks to evaluate the architectural solution only, through a qualitative way, thus making it contrary to the formula based setup of DGNB. The categories are called "first draft" because the Diamond initiative is still on the drawing board.

All four participants liked and acknowledged the general aim of the Diamond initiative, and some participants said that it definitely was needed. They all saw a potential in it and that the initiative could give the architectural aspect in DGNB the needed lift of importance. The weakness of the first draft was that Diamond lacked integration with the rest of the DGNB and that its approach were different compared to DGNB's formula based setup.

Conclusion

Theory research aspect

The LCA and the LCC were both found as key criteria of DGNB due to their size and interrelations, and it was recommended to address them iteratively throughout the design process. The local environmental impact was found to be a considerable obstacle due to its documentation requirements. A company's CSR-policy was a good framing of which DGNB criteria that could be defined as a project's key criteria. However, the design team should also agree upon which way the rest of the DGNB points should be obtained. A project brief had to include specific requirements to DGNB parts, to secure a uniform approach and level of ambition for the design team. Lastly it is important to be create early

concepts through workshops because it adjusted expectations and increased understanding.

Workflow

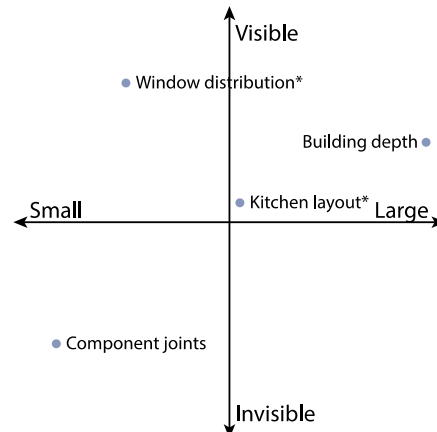
Specific requirements for the workflow had to be implemented in the contract to secure a good basis for the collaboration. The requirements directly from DGNB were also important to incorporate, which is a finding many other studies support. The early stage assessment with DGNB was recommended to be made through a qualitative assessment, and the general assessment should keep a holistic perspective with an iterative assessment to the largest criteria. The increased level of documentation could be a challenge due to resistance in the design teams, and to accommodate this specific actions should be performed early in the design phases.

Architecture

DGNB had an impact on the architecture since it provoked certain architectural traits through its requirements. This led the architects to tweak their mindset to design for DGNB points. These traits were present in every part of the building and varied in size and visibility. The building's quality was generally lifted by DGNB because it placed requirements to all aspects of a building, while at the same time demanding an evaluation of the quality of the solutions in all dimensions through different tools. However, the aesthetical/architectural quality is evaluated insufficiently by different criteria resulting in the aesthetical quality struggling for importance. The new initiative called Diamond that has to accommodate this issue was evaluated to have the potential to give the aesthetical quality weight.

The participants all agreed to DGNB making them design the building in certain ways since it resulted in a higher amount of achievable points. Furthermore some participants did also note that they were unaware that this happened for them, and defined it to be happening on different levels or scales. The participants could nevertheless not give specific examples. In any case, one could argue that every criteria, to some degree, has an impact on the architecture and thus creating architectural traits, however, it vary in how explicit it is and also in size or scale. One participant noted for example the DGNB requirement called Design for Disassembly, and how it should bring back some old traditions of creating joints of building components. This requirement surely has an impact on the architecture, but in another level compared to the requirements the overall geometry in criterion ECO 2.1 - Flexibility and adaptability. The result is different architectural impacts that can be mapped on a 2D-plot with scale and visibility as the two axes, as seen in Figure 5.

Figure 5. Indexing architectural traits depending on scale/size and visibility. The elements marked with * is criteria from DGNB dwellings scheme.



buildings. Likewise one participant mentioned the oil crisis in Denmark in the 80's as another example of requirements that lead to other architectural traits and then compared the requirements in DGNB with the impacts of the oil crisis. The question now should rather be how much, and how subtle, the BSATs should create or provoke architectural traits, and it should be discussed more in public, according to one participant that furthermore hopes the DGNB impact on architectural traits is a temporary tendency.

It is visible, when turning to the architectural quality, that DGNB has a tendency to have an impact on the architectural quality, which goes in both directions and on different levels. Criterion TEC 1.6 - Deconstruction and Disassembly was mentioned by one participant as a criterion that lifted the architectural quality because it opposed solutions optimized only in relation to the construction cost /the economic dimension, such as casted concrete joints (which makes 'design for disassembly impossible). The participants generally saw potentials in the new initiative Diamond, but they were also a bit skeptical about the integration. It could be that the initiative would end up being similar as the site assessment in DGNB that does not have any influence on the total score.

Discussion

Looking at the very aim of a BSAT it is not explicit that such a system should interfere with our way of designing buildings since the general goal is to push forwards towards the sustainable building and away from the current environmental impact. The ideal future solution to this issue could be when the environmental and economic challenges in

Brundtlands sustainability definition is resolved. Architecture would then only have to contribute and create value to the social element. Technical solutions have been optimized for economy within the limits of law of e.g. environment. Yet the nature of DGNB, or any BSAT, goes against this imbalance by demanding an evaluation of the quality of the solutions in all dimensions through different tools such as the LCC, energy calculations or other. Especially the technical quality has been underlined in DGNB as an important parameter for the building, but its contrary, as found through this research, might just be the aesthetical quality of the building because it lacks a direct evaluation and therefore also possible points given. Conclusively one can argue that DGNB has a general aim of increasing the quality in its five categories, yet there is a problem within the social category since the aesthetical/Architectural quality lacks presence in the explicit criteria evaluation and thus struggles to get prioritized when designing for ambitious DGNB goals. The lack of aesthetical quality underlines the need for the Diamond initiative that has the aim of bringing more focus to this unquantifiable element.

References

- AIA (2007) Integrated Project Delivery: A guide. *American Institute of Architects*.
- Brunsgaard, C. (2016) Sustainability Certification (DGNB) and Design Process in the Case of four Healthcare Centres. *CLIMA 2016 - proceedings of the 12th REHVA World Congress*.
- Charmaz, K. (2006) Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis. Sage Publications, London.
- DGBN (2016) The DGNB Certificate System. Retrieved September 26, 2015 from: http://www.dgnb-system.de/en/index_2015.php
- Ding, G.K.C. (2008) Sustainable construction - The role of environmental assessment tools. *Journal of Environmental Management*, Vol. 86(3), pp. 451-464.
- Ebert, T., Eißig, N., Hauser, G. (2011) Green Building Certification Systems: Assessing sustainability - International system comparison - Economic impact of certifications. *DETAIL*. Munich.
- Evins, R. (2013) A review of computational optimisation methods applied to sustainable building design. *Renewable and Sustainable Energy Reviews*. Vol. 22, pp. 230-245.
- Khezri, N. (2011) Building Environmental Assessments and Low Energy Architecture, A comparative analysis of three methods. *AAR4817 Use and Operation of Zero Emission Buildings*, pp. 1-24.
- Kreiner, H., Passer, A., Wallbaum, H. (2015) A new systemic approach to improve the sustainability performance of office buildings in the early design stage. *Energy and Buildings*, Vol. 109, pp. 385-396.
- Lee, A.S. (1991) Integrating Positivist and Interpretive Approaches to Organizational Research. *Organization Science*. Vol. 2(4), pp. 342-365.
- Löhnert, G., Dalkowski, A., Sutter, W. (2003) Integrated Design Process: a guideline for sustainable and solar-optimised building design. IEA International Energy Agency, Berlin.
- Medineckiene, M., Zavadskas, E. K., Björk, F., Turskis, Z. (2015) Multi-criteria decision-making system for sustainable building assessment/certification. *Archives of Civil and Mechanical Engineering*. Vol 15(1), pp. 11-18.
- Naboni, E. (2013) A unified tool to design and define Architectural. *EAEA-11 Conference*, Milano.
- Rockström, J. et al. (2009) Planetary boundaries: Exploring the safe operating space for humanity. *Nature*, Vol. 461, pp. 472-475.
- Schweber, L. (2013) The effect of BREEAM on clients and construction professionals. *Building Research & Information*, Vol. 41(2), pp. 129-145.
- Schweber, L., Haroglu, H. (2014) Comparing the fit between BREEAM assessment and design processes. *Building Research & Information*, Vol. 42(3), pp. 300-317.
- Schweber, L. and Leiringer, R. (2012) Beyond the technical: a snapshot of energy and buildings research. *Building Research and Information*, Vol. 40 (4). pp. 481-492.
- Secretariat of the Convention on Biological Diversity (2014) Global Biodiversity Outlook 4 — Summary and Conclusions. Montréal, 20 pages.
- UN-Habitat (2009) Planning Sustainable Cities – Global Report on Human Settlements 2009, *Earthscan*.
- UNEP SBCI (2013). Buildings and Climate Change - Summary for Decision-Makers, Paris.
- Wallhagen, M., Glaumann, M., Eriksson, O., Westerberg, U. (2013) Framework for detailed comparison of Building Environmental Assessment Tools. *Buildings*, Vol. 3(1), pp. 39-60.
- Yuce, M. (2012) Sustainability Evaluation of Green Building Certification Systems. Florida International University, Florida.